Stochastic Cooling for RHIC

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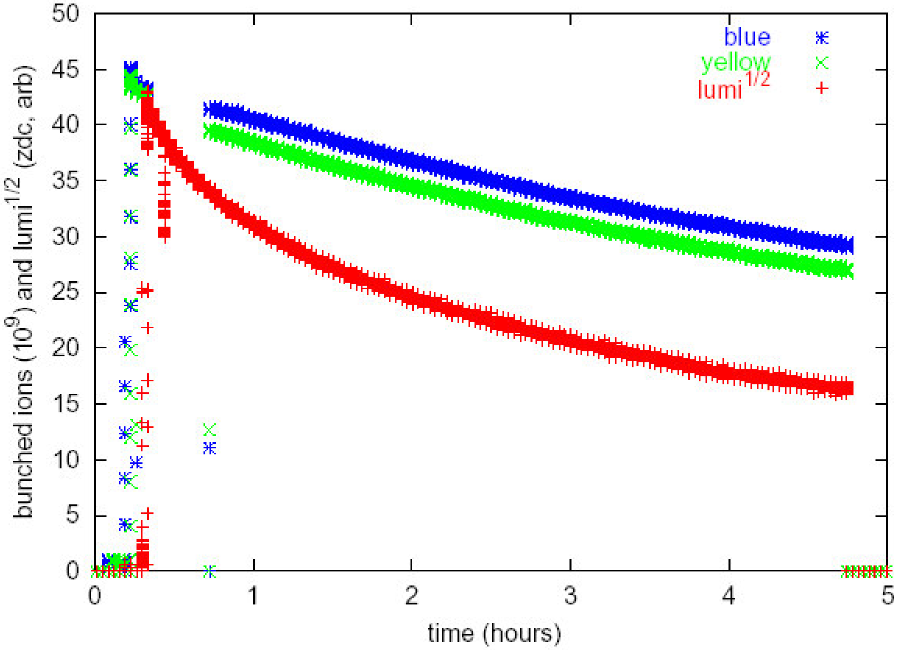
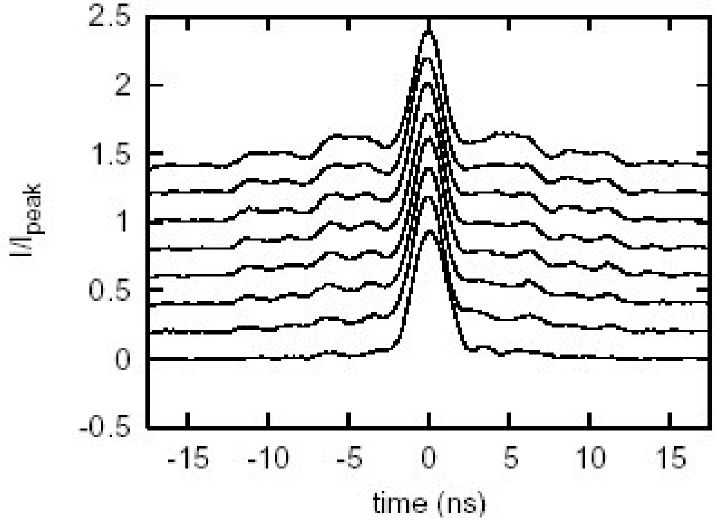
Goal: To provide microwave stochastic cooling at a level which will improve integrated luminosity by a significant factor (maybe 2) within the next few years. Confine beam halo when electron cooling arrives.





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From J.M. Brennan's MAC presentation

Bunched-beam Stochastic Cooling

- What would be required,
  - –Cooling time would have to be commensurate with de-bunching time, ~ few hours
  - –Cool only large ΔP particles (halo cooling)
- Consider coasting beam theory (full bucket)

$$\frac{1}{\tau} = \frac{W}{N_{eff}}\left[2g\left(1-\tilde{M}^{-2}\right) - g^2\left(M+U\right)\right] \qquad g_{optimum} = \frac{1-\tilde{M}^{-2}}{M+U} \cong \frac{1}{5}$$

$$\frac{1}{\tau_{opt}} = \frac{W}{N_{eff}}\left[\frac{\left(1-\tilde{M}^{-2}\right)^2}{M+U}\right] = \frac{1}{3000\ \mathrm{sec}} \qquad N_{effective} = \frac{10^9}{1.5\mathrm{m}}3830\mathrm{m} = 2.5\mathrm{x}10^{12}$$

- Why wasn't stochastic cooling in the base line design for RHIC?
- High frequency bunched-beam stochastic cooling is required

Highlights from last year

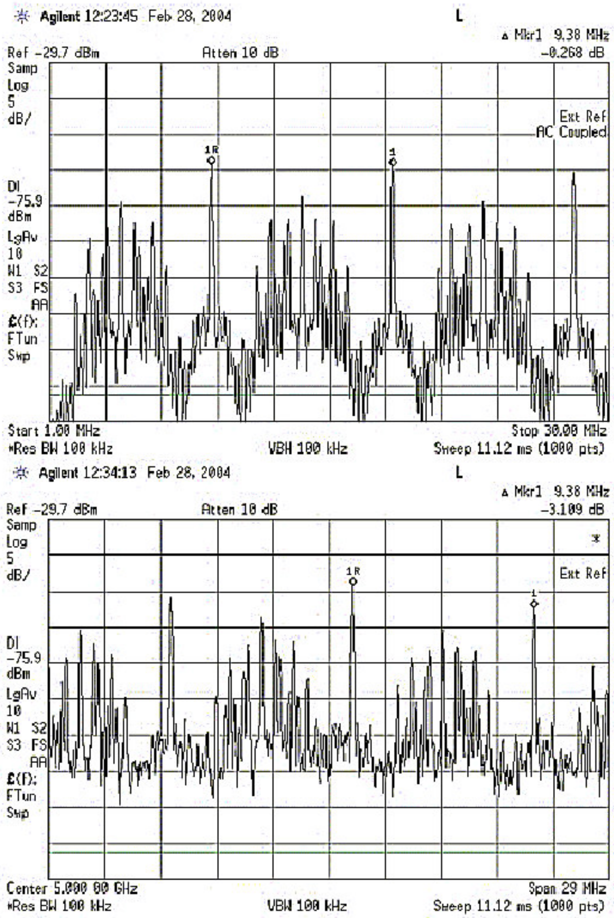


Figure 2: High and low frequency gold spectra with a span 29 MHz and a resolution bandwidth of 100 kHz. The generic features of the spectrum do not change between baseband and 5 GHz.

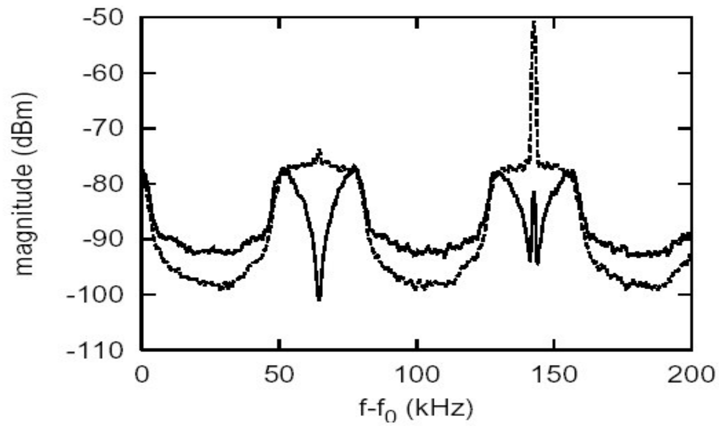


Figure 1: Gold Schottky spectra with (solid) and without (dashed) the one turn delay notch filter, $f_0 = 4.77$ GHz.

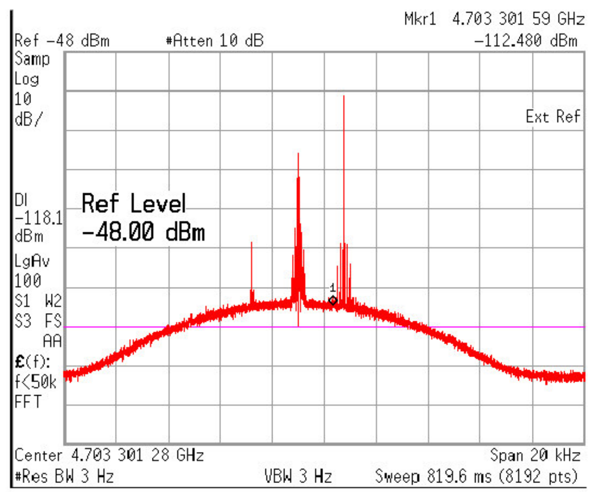


Figure 3: High resolution proton Schottky spectrum.

$$-\frac{2a^3\lambda}{\ell} = G_b(r)/r^2 - G_a(r) \approx -0.77r\ln(r)/(1+r), \tag{32}$$

Voltage considerations

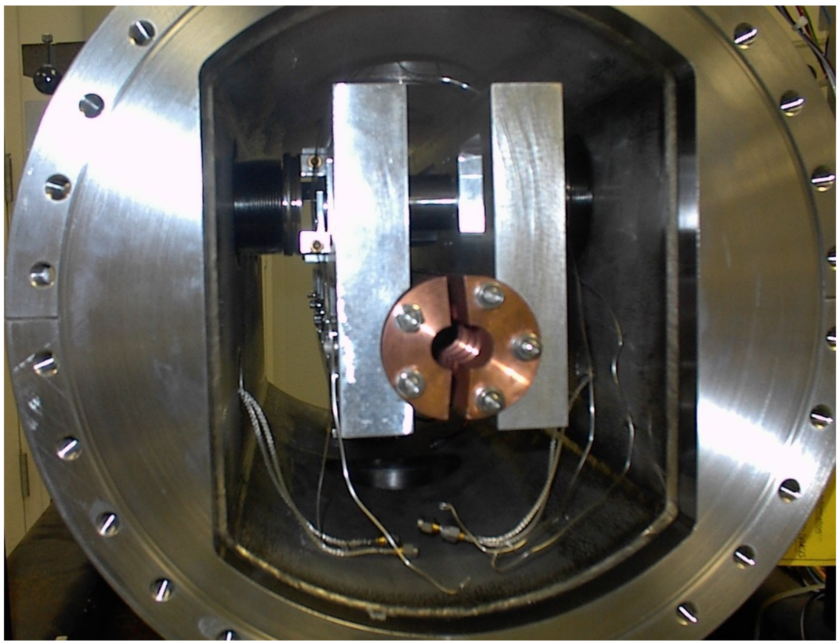
For 4-8 GHz need 1 to 3.6 kV rms, large by stochastic cooling standards

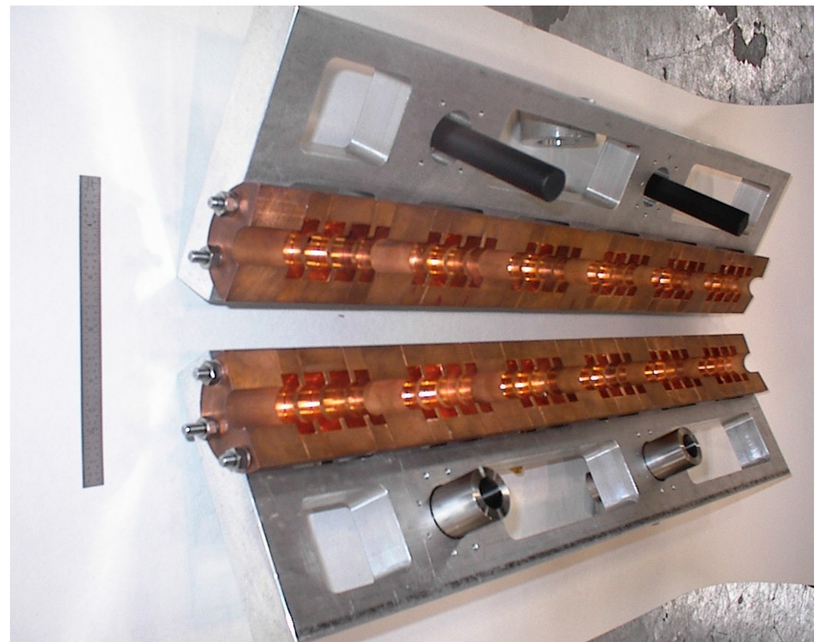
Bunches are $\tau_b = 5$ ns long spaced by at least 100 ns

The value of the kicker voltage matters only when the bunch is present

$$V(t) = \sum_n A_n \sin(2\pi n t / \tau_b + \theta_n)$$

Where A_n and θ_n vary smoothly between bunches





Voltage and Power part 2

Take 21 cavities, 4-8 GHz bandwidth 40 Watts/cavity (10 K each)

R/Q=100Ω, 10 MHz FWHP bandwidth

gives 1.2 kV rms per cavity, or 5.6 kV total

Cavity drive signal needs to be roughly sinusoidal for R (not R/Q) to matter

Suppose $S_0(t)$ is the drive signal for a broad band kicker (like a resistor).

Periodically extend
$$S(t) = \sum_{k=0}^{15} S_0(t - k\tau_b)$$

Split and pass through 100 MHz filters, centered on cavity resonance, before power amps. In this way each amplifier sees a piecewise sinusoidal input.

The delay lines are being built with a 16 way fiber optic splitter, fiber optic delay lines, and a fiber optic combiner.

We are primarily interested in confinement within the bucket ,

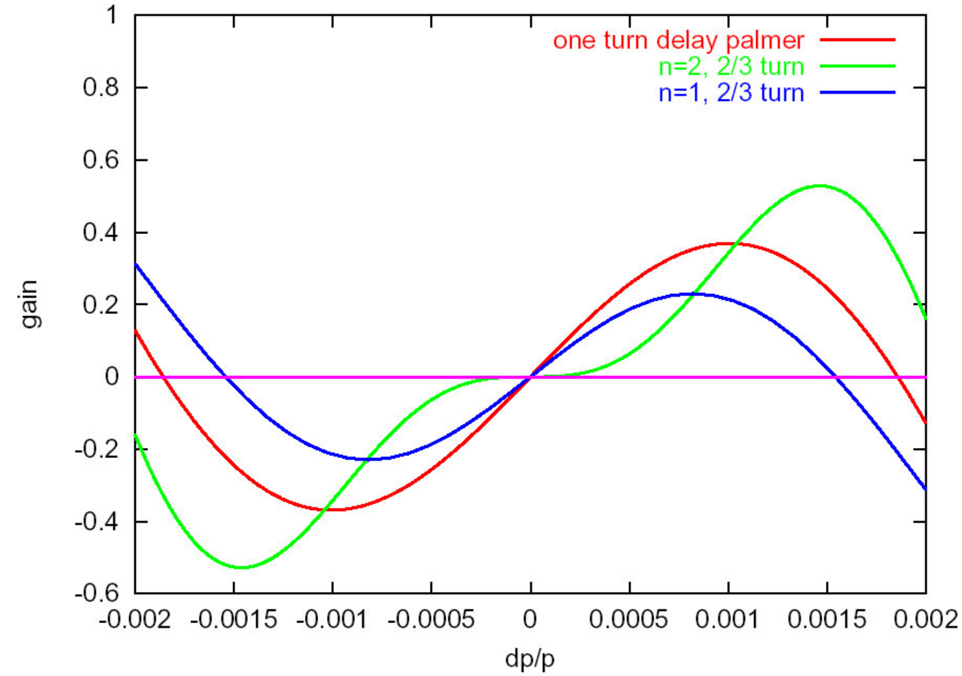
so we focus on halo particles

Low Level Drive

For cooling we need a force proportional to the energy error.

Without a specially designed lattice, an expert (D. McGinnis) suggested we use filter cooling.

$$S(t) = G(1 - e^{-j\omega T_{rev}})^n I_b e^{j\omega(t - T_d)}$$



The delay lines are done in fiber optics.

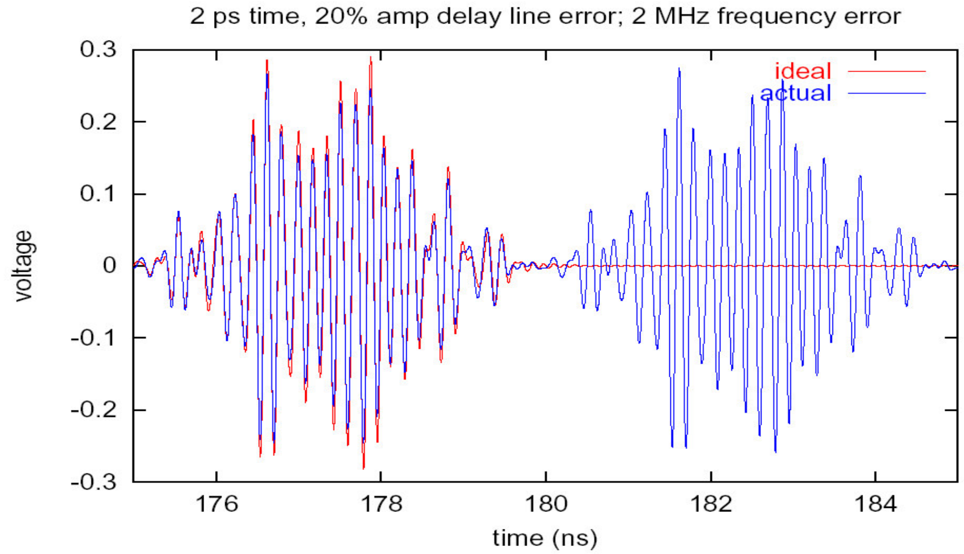
Simulation results

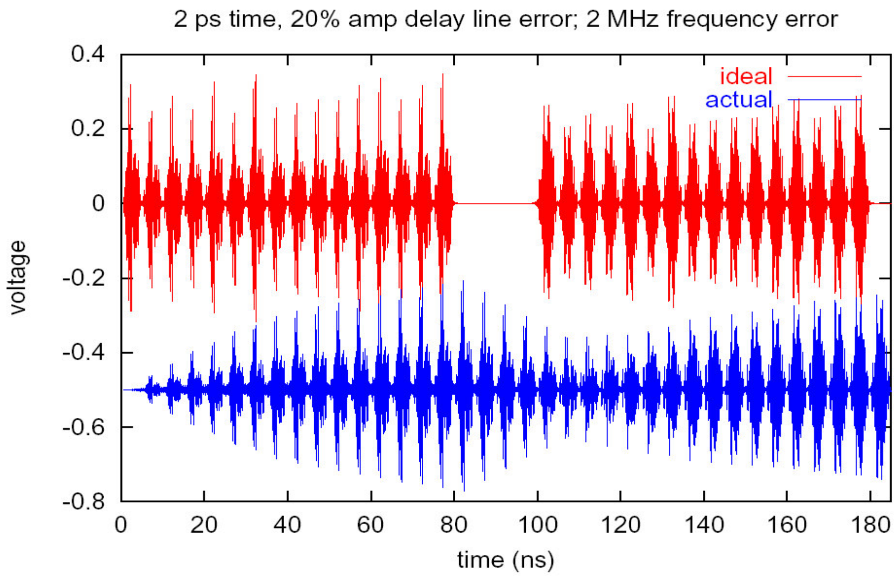
Took reasonable errors.

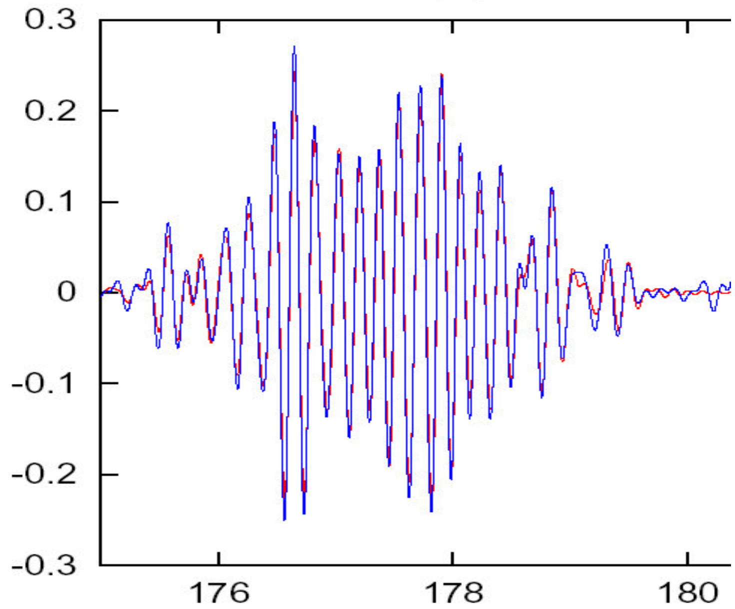
Timing is OK and straightforward

Delay line gain is main problem but can be fixed with variable attenuators, if needed (LR).

Frequency error is tougher to improve but not a problem at this level.







Plan for this run

- Installing 7-8 GHz and 4-5 GHz kickers in yellow 4 o'clock
- 16 channel delay line and full turn delays are in process
- Have 5 amplifiers in hand and more on order
- For full comparison with Au beams need 1.e9 ions in a witness bunch
- We should get a clean cooling signal albeit at about ½ the expected rate for the full system.
- Required voltage/cavity very similar to that needed for Au.
- All this assumes rebucketed beam. An experiment without rebucketed beam might be worthwhile.